METHOD AND DEVICE FOR GENERATING A CONSTANT ENVELOPE NAVIGATION SIGNAL WITH FOUR INDEPENDENT CODES

The invention concerns a method and device for generating, on
5 board a space satellite or from a terrestrial beacon
(pseudosatellite), a modulated navigation signal for
positioning a downlink receiver, comprising four pseudorandom
navigation codes of frequency greater than 0.5 MHz which are
modulated onto the same carrier of frequency fp greater than
10 500 MHz, typically between 1000 MHz and 1700 MHz.

The generation of modulated navigation signals such as those
which are encountered for the GPS or Galileo constellations
or other systems such as GLONASS, KOMPASS, BEIDOU or the
15 pseudosatellites is specific, and in particular completely
distinct from what is encountered for telecommunication
signals carrying information and data.

In fact, a navigation signal for positioning a downlink
20 receiver essentially carries pseudorandom codes which are
formed of digital sequences of high frequency cadence,
repeated over a very long period, the main function being to
make it possible to date the emission and not to transmit
digital data. At least one of the pseudorandom codes can
25 also, secondarily, carry data (digital data or navigation
messages such as position of satellite(s), drift of onboard
clock, ionospheric corrections, almanacs or ephemerides,
etc.), but at a much lower rhythm (typically 25 to 500 bit/s,
whereas the frequency of the pseudorandom code is greater
30 than 0.5 MHz).

The receiver compares each pseudorandom code with a replica,
in such a way as to determine the "pseudodistance"

corresponding to the sum of the trip time and the clock skew between the emitting satellite and the receiver.

The publication "Status of Galileo Frequency and Signal
5 Design" by Guenter W. HEIN, Jeremie GODET, Jean-Luc ISSLER, Jean-Christophe MARTIN, Philippe ERHARD, Rafaël LUCAS-RODRIGUEZ, Tony PRATT, 25/09/2002, http//europa.eu.int/comm/dgs/energy_transport/galileo/ documents/technical_en.htm, describes the various modulation
10 schemes which are known and can be imagined to implement a modulated navigation signal.

In particular, for modulation in the E5 band which must transmit four navigation codes in a 10 MHz cadence, this
15 document provides either two QPSK signals on two distinct bands E5a, E5b (two distinct carriers, multiplexed), or a single broadband signal which is generated according to a modulation of the type called BOC ("binary offset carrier"), using a square subcarrier. The advantage of modulation of BOC
20 type is actually to make it possible to transmit multiple codes on a single carrier, resulting in identical skews. BOC modulation also makes it possible to avoid degrading the signal-to-noise ratio. In fact, it makes it possible to do without multiplexers, and thus to limit the losses in the
25 payload and to transmit the secondary lobes of the signal if they exist. Additionally, because a single amplification chain is used, the variations of the propagation time of the various codes are correlated, resulting in improved performance.
30

The above-mentioned document is also a reminder of the importance of generating the modulated signal with a constant envelope, in such a way as to be able to optimize the

functioning of the power amplifier, and to avoid having to provide a linear amplifier and/or one which has a certain backoff (and therefore less efficiency), has greater volume, and is heavier. Concerning this, it should be noted that the

5 problem is particularly important to the extent that the power amplifier represents the greatest part of the mass and volume of the onboard electronic circuit for emitting the navigation signal. As the above-mentioned document indicates, the use of alternative (or baseband) BOC modulation

10 comprising a complex rectangular subcarrier (which is interesting, in particular, because it can be generated in digital form) was considered. But if transmission of four codes with such modulation is desired, a navigation signal with non-constant envelope, and of which the value may even

15 be zero, is necessarily obtained. The same happens if a sinusoidal subcarrier is used. This is why this document announces the use of a variant which makes it possible to generate the four codes with a constant envelope by 8-PSK modulation, but does not describe at all the method or device

20 which makes it possible to obtain such a surprising result.

The invention is thus aimed at proposing a method and device for generating such a broadband modulated navigation signal, which can carry four pseudorandom navigation codes on the

25 same carrier while presenting a constant envelope.

To do this, the invention concerns a method of generating – in particular on board a space system – a modulated navigation signal which is intended to be used to position a

30 downlink receiver, comprising multiple pseudorandom navigation codes of chip rhythms greater than 0.5 MHz, modulated onto a carrier of frequency fp greater than 500 MHz, wherein four pseudorandom navigation codes C1, C2,

C1', C2' are modulated onto the carrier according to an 8-PSK modulation of constant amplitude with a modulation frequency fM such that:

5
$$8fc \leq fM$$

where $fc = Max(fci)$, and fci designates the chip rhythms fc1, fc1', fc2, fc2' of the navigation codes C1, C2, C1', C2', each fci value being such that $fM = Ni.fci$, Ni being an
10 integer greater than or equal to 8, two navigation codes C1, C1' being quadrature modulated at frequency $f1 = fp-fM/8$, and two other navigation codes C2, C2' being quadrature modulated at frequency $f2 = fp+fM/8$, and the modulated navigation signal presenting a constant envelope.
15

The navigation signal according to the invention has a spectral separation of the codes, which are distributed in two main lobes around the carrier frequency.

20 Advantageously and according to the invention, fM is chosen to be $\leq$ 400 MHz. More particularly, in the case of a method which is implemented on board a space system, fM is chosen to be $\leq$ 200 MHz.

25 It can be seen that such modulation actually corresponds to LOC ("linear offset carrier") modulation with a sinusoidal subcarrier of frequency fM/8, but made discrete so that only the points which correspond to the 8-PSK constant amplitude constellation are addressed. In this way, surprisingly,
30 transmission on a single carrier of four distinct, independent pseudorandom navigation codes combined on a single baseband modulation signal of constant envelope at output is achieved, with a spectral occupation centered on f1

for C1 and C1' and on f2 for C2 and C2', and with a small gap between f1 and f2 (less than 100 MHz), in particular less than 50 MHz on board a space system). In particular, it should be noted that with such a small frequency gap, the

5 solution which would consist of multiplexing the modulated and amplified signals separately for each frequency f1, f2 would not give satisfactory practical results, particularly on board a space system. In fact, this solution would make excessively narrow filtering of each of the modulated signals

10 necessary, resulting in loss of quality of the navigation signal and making it useless in practice.

Additionally, the condition that $8fc \leq fM$ makes it possible to ensure that the frequency of the subcarrier is greater

15 than the chip rhythm of the pseudorandom codes.

Advantageously and according to the invention, 8-PSK modulation of symmetrical constant amplitude in the Fresnel plan is used. In a variant, 8-PSK modulation of asymmetrical

20 constant amplitude in the Fresnel plan is used.

Advantageously and according to the invention, 8-PSK modulation of phase states equal to $k.\pi/4$, where k is an integer between 1 and 8, is used. Thus for pseudorandom codes

25 taking the values 1 and -1, the baseband modulation signal can take the following values:

$$2.\exp[jk.\pi/4], \quad k \; \varepsilon \; \{1,2,3,4,5,6,7,8\}$$

30 Advantageously and according to the invention, the four codes are modulated according to a truth table which is chosen from the group of truth tables formed from:

TABLE 1

C1(t)	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1
C2(t)	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	1
C1'(t)	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1
C2'(t)	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1
t modulo 8TM																
[0,TM[	P5	P4	P4	P3	P6	P7	P5	P2	P6	P1	P3	P2	P7	P8	P8	P1
[TM,2TM[	P5	P8	P4	P3	P6	P7	P5	P6	P2	P1	P3	P2	P7	P8	P4	P1
[2TM,3TM[	P1	P8	P4	P7	P6	P7	P5	P6	P2	P1	P3	P2	P3	P8	P4	P5
[3TM,4TM[	P1	P8	P8	P7	P2	P7	P5	P6	P2	P1	P3	P6	P3	P4	P4	P5
[4TM,5TM[	P1	P8	P8	P7	P2	P3	P1	P6	P2	P5	P7	P6	P3	P4	P4	P5
[5TM,6TM[	P1	P4	P8	P7	P2	P3	P1	P2	P6	P5	P7	P6	P3	P4	P8	P5
[6TM,7TM[	P5	P4	P8	P3	P2	P3	P1	P2	P6	P5	P7	P6	P7	P4	P8	P1
[7TM,8TM[	P5	P4	P4	P3	P6	P3	P1	P2	P6	P5	P7	P2	P7	P8	P8	P1

TABLE 2

5

C1(t)	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1
C2(t)	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	1
C1'(t)	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1
C2'(t)	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1
t modulo 8TM																
[0,TM[	P1	P8	P4	P7	P6	P7	P5	P6	P2	P1	P3	P2	P3	P8	P4	P5
[TM,2TM[	P1	P8	P8	P7	P2	P7	P5	P6	P2	P1	P3	P6	P3	P4	P4	P5
[2TM,3TM[	P1	P8	P8	P7	P2	P3	P1	P6	P2	P5	P7	P6	P3	P4	P4	P5
[3TM,4TM[	P1	P4	P8	P7	P2	P3	P1	P2	P6	P5	P7	P6	P3	P4	P8	P5
[4TM,5TM[	P5	P4	P8	P3	P2	P3	P1	P2	P6	P5	P7	P6	P7	P4	P8	P1
[5TM,6TM[	P5	P4	P4	P3	P6	P3	P1	P2	P6	P5	P7	P2	P7	P8	P8	P1
[6TM,7TM[	P5	P4	P4	P3	P6	P7	P5	P2	P6	P1	P3	P2	P7	P8	P8	P1
[7TM,8TM[	P5	P8	P4	P3	P6	P7	P5	P6	P2	P1	P3	P2	P7	P8	P4	P1

where P1, P2, P3, P4, P5, P6, P7, P8 are the various contacts
and the 8-PSK constellation, and TM = 1/fM, and other truth
tables derived from these truth tables TABLE 1 and TABLE 2 by
phase rotation by n.π/4, n ε {1,2,3,4,5,6,7} and/or reversal
of the direction of the path of the constellation. The
changes of state of one combination of the four codes to
another take place in a pseudorandom fashion according to a
frequency which is a multiple of fM (including fM itself).
Advantageously and according to the invention, fp is between
1000 MHz and 1700 MHz (band L). Advantageously and according
to the invention, fc is of the order of 10 MHz.
Advantageously and according to the invention, fM is of the
order of 120 MHz. Advantageously and according to the
invention, in at least one pair of codes C1, C1'; C2, C2'
which are quadrature modulated onto the same frequency, one
C1'; C2' incorporates digital data which is modulated
according to a frequency less than fc/1000. Thus each pair of
codes can incorporate digital data.

The invention extends to a device for implementing a method
according to the invention. The invention thus concerns a
device for generating - in particular on board a space system
- a modulated navigation signal which is intended to be used
to position a downlink receiver, comprising multiple
pseudorandom navigation codes of chip rhythms greater than
0.5 MHz which are modulated onto a carrier of frequency fp
greater than 500 MHz, this device comprising:

-       a circuit to generate pseudorandom navigation codes,

-       a phase-shifting modulator circuit which supplies the
        modulated navigation signal on the carrier,

- an emitter circuit, comprising at least one power amplification stage, and suitable for emitting a radio frequency signal corresponding to the modulated navigation signal,

5

wherein the modulator circuit is suitable for modulating, on the carrier, four random navigation codes C1, C2, C1', C2' according to an 8-PSK modulation of constant amplitude with a modulation frequency fM such that:

10

$$8fc \leq fM$$

where $fc = Max(fci)$, and fci designates the chip rhythms $fc1$, $fc1'$, $fc2$, $fc2'$ of the navigation codes C1, C2, C1', C2',

15 each fci value being such that $fM = Ni.fci$, Ni being an integer greater than or equal to 8, two navigation codes C1, C1' being quadrature modulated at frequency $f1 = fp-fM/8$, and two other navigation codes C2, C2' being quadrature modulated at frequency $f2 = fp+fM/8$, and the modulated navigation

20 signal presenting a constant envelope.

Advantageously and according to the invention, the modulator circuit is suitable for implementing an 8-PSK modulation with a modulation frequency $fM \leq 400$ MHz. In particular, in the

25 case of a device which is intended to be placed on board a space satellite, advantageously and according to the invention, the modulator circuit is suitable for implementing an 8-PSK modulation with a modulation frequency $fM \leq 200$ MHz.

30 Advantageously and according to the invention, the modulator circuit is suitable for implementing an 8-PSK modulation of symmetrical constant amplitude in the Fresnel plan.

As a variant, the modulator circuit is suitable for implementing an 8-PSK modulation of asymmetrical constant amplitude in the Fresnel plan.

5 Advantageously and according to the invention, the modulator circuit is suitable for implementing an 8-PSK modulation with phase states equal to $k\pi/4$, k being an integer between 1 and 8. Advantageously and according to the invention, the modulator circuit is suitable for modulating the four codes
10 according to a truth table as described above. Advantageously and according to the invention, fp is between 1000 MHz and 1700 MHz. Advantageously and according to the invention, fc is of the order of 10 MHz. Advantageously and according to the invention, fM is of the order of 120 MHz. Advantageously
15 and according to the invention, the device is suitable so that, in at least one pair of codes C1, C1'; C2, C2' which are quadrature modulated onto the same frequency, one, C1', C2' incorporates digital data which is modulated according to a frequency less than fc/1000.
20

The invention thus makes it possible, very simply, to transmit, by a single modulated navigation signal, four independent pseudorandom codes, by 8-PSK modulation which can be assimilated to LOC modulation with a sinusoidal subcarrier
25 which is made discrete so that only the points of constant amplitude are selected.

The invention also concerns a method and a device which in combination have all or some of the characteristics mentioned
30 above or below.

Other aims, characteristics and advantages of the invention appear on reading the following description, which refers to the attached figures, in which:

5 -   Fig. 1 is a diagram of a constellation of navigation satellites such as GPS or Galileo,

-    Fig. 2 is a circuit diagram of a device according to the invention,

10

-    Fig. 3 is a circuit diagram of a circuit of a receiver for a modulated navigation signal for positioning by downlink,

15 -   Fig. 4 is a more detailed diagram of a part of the device of Fig. 2 according to the invention,

-    Figs. 5 and 6 are diagrams representing two examples of possible architectures of receivers which are compatible

20   with a method and a device according to the invention,

-    Fig. 7 is a diagram representing an example of the timing diagrams of the navigation codes and the paths I, Q of a navigation signal in a method according to the

25   invention,

-    Fig. 8 is a diagram in the Fresnel plan, representing an 8-PSK modulation constellation which can be used in a method according to the invention,

30

-    Fig. 9 is an example of a diagram representing a navigation signal spectrum of a method according to the invention,

-    Fig. 10 is a diagram representing the spectrum of the
     signal of Fig. 9 filtered by a filter of central
     frequency fp and allowing the two main lobes at
5   frequencies f1 and f2 and secondary lobes to pass,

-    Fig. 11 is a diagram representing the spectrum of the
     signal of Fig. 9 filtered by a filter of central
     frequency f1 and allowing only the main lobe at f1 and
10   parts of secondary lobes to pass,

-    Fig. 12 is a diagram representing an example of a
     correlation function which is used in a receiver, and
     corresponding to the navigation signal of Fig. 11.
15

The device according to the invention is intended to be
placed on board a space system such as a satellite 2a, 2b,
2c, 2d belonging to a constellation 1 of satellites which are
suitable for allowing radio navigation and/or radio
20 positioning of receivers 6 on Earth or on a terrestrial
satellite -particularly terrestrial receivers or receivers on
board satellites or aircraft-. In particular, the invention
is intended for equipping satellites of the Galileo
constellation for emitting navigation codes in the E5 band.
25

A device according to the invention can also, as a variant or
in combination, be used in pseudolites (or pseudosatellites),
which are beacons, generally on the ground, which generate a
navigation signal which is close to a navigation signal which
30 a satellite broadcasts.

Each satellite 2a, 2b, 2c, 2d thus includes a device
according to the invention for generating a modulated

navigation signal 7a, 7b, 7c, 7d comprising multiple
pseudorandom navigation codes which are intended to be used
to position the downlink receiver 6.

5 This generating device comprises a receiving antenna 8 which
is associated with a circuit 9 to receive the data, in such a
way that the generating device can receive navigation data or
messages – in particular coming in general from the ground,
for management of the constellation 1 by the ground control
10 segment – which can be incorporated in whole or in part into
the modulated navigation signal.

The generating device also includes a clock circuit 10 which
supplies a reference frequency f0 to a circuit 11 for
15 generating navigation codes, and to a circuit 12 for
generating the carrier signal. The circuit 11 for generating
navigation codes may receive data from the data receiver 9.
The navigation codes from the circuit 11 are modulated by a
modulator circuit 13 onto the carrier signal from the
20 circuit 12. The thus obtained modulated signal is delivered
to an emission antenna 14 via an amplification and filtering
emitter circuit 15, in such a way that the emission
antenna 14 emits the modulated navigation signal 7 which
carries the various pseudorandom navigation codes.
25

This navigation signal 7 is received by a receiver 6, the
circuit diagram of which is shown in Fig. 3. This receiver 6
comprises a reception antenna 18 which is associated with a
radio frequency reception circuit 19 which comprises, in
30 traditional fashion, an amplification, filtering, frequency
conversion and analog/digital conversion chain. This radio
frequency reception circuit 19 thus supplies a digital
modulated signal to signal processing circuits 20, i.e. a

circuit 20a, 20b, 20c, 20d for each navigation signal 7a, 7b, 7c, 7d from each satellite 2a, 2b, 2c, 2d, in such a way as to allow simultaneous processing of these signals. It should be noted that it is possible to use more than four

5 satellites, and thus more than four processing circuits 20, in a receiver.

Each signal processing circuit 20 makes it possible to extract crude measurements 21 and, if applicable, navigation

10 data (or messages) 22 carried by one and/or the other of the codes of the received modulated navigation signal. The crude measurements 21 consist, in particular, of a calculation of the pseudodistance between the corresponding 2a, 2b, 2c, 2d and the receiver 6. It can also be a so-called "pseudospeed"

15 or "integrated Doppler" calculation which is implemented on the carrier signal. These crude measurements are traditional and well known, particularly in the case of the GPS constellation.

20 These calculations, as well as all the known concepts concerning navigation and positioning by satellite, are described, for example, in the document UNDERSTANDING GPS: PRINCIPLES AND APPLICATIONS, Elliott D. KAPLAN, published by Artech Housse, 1996.

25

The crude measurements 21 and the navigation data 22 if any are supplied to a navigation calculation circuit 23, which supplies, on the one hand, the crude measurements 21 and navigation data 22 which it receives, and on the other hand,

30 a calculation result 24, in particular a position signal of the receiver 6.

It should be noted that very many different known
technologies and architectures for such a receiver 6 exist,
in particular concerning the various signal processing
circuits and the navigation calculation. The signals from the
5   circuit 23 are supplied if appropriate to a digital
processing device, for subsequent exploitation for navigation
or positioning.

The receiver 6 also comprises a clock circuit 25, which
10 supplies a reference frequency on the one hand to the radio
frequency reception circuit 19, and on the other hand to the
various signal processing circuits 20.

Fig. 4 represents, in more detail, block 16, which comprises
15 circuits 9, 10, 11, 12, 13 (represented in Fig. 2 by dotted
lines), and which makes it possible to implement the method
according to the invention.

This block 16 comprises the clock circuit 10 which generates
20 an analog clock signal at the reference frequency fo, which,
for example, is of the order of 10.23 MHz. This reference
frequency fo is supplied to a circuit 26, which generates
square signals, the cadence of which is based on the
reference frequency f0. These square signals at the reference
25 frequency f0 are supplied to four frequency converters 27-1,
27-1', 27-2, 27-2', which supply square signals of frequency
fc1, fc1', fc2, fc2' respectively to four pseudorandom
navigation code generator circuits 28-1, 28-1', 28-2, 28-2',
which generate respectively four independent pseudorandom
30 navigation codes C1, C1', C2, C2', which are intended to be
incorporated into the navigation signal 7. The circuit 26,
which generates square signals at frequency f0, also supplies
these square signals to a frequency converter 29, which

supplies square signals at a frequency fM, which is the
modulation frequency, to a cyclical counter 30, which makes
it possible to generate eight digital values, from 1 to 8,
cyclically, so that the cadence of the modulator circuit 13
5 is based on the modulation frequency fM.

A reinitialization circuit 31 makes it possible to initialize
and synchronize, at startup, the four code generator circuits
28-1, 28-1', 28-2, 28-2', as well as the counter 30, and thus
10 the modulator 13.

The data receiver circuit 9 supplies navigation data
(messages) as appropriate to one and/or the other of the code
generator circuits 28-1, 28-1', 28-2, 28-2', in such a way
15 that this navigation data can be integrated into the
pseudorandom code, but at a much lower frequency. The four
circuits 28-1, 28-1', 28-2, 28-2' form the circuit 11 shown
in Fig. 2, the function of which is to generate the
pseudorandom navigation codes.
20

The modulator circuit 13 is suitable for implementing the
modulation in conformity with the method of the invention,
according to a constant amplitude 8-PSK modulation with a
modulation frequency fM which is defined by the signals which
25 the counter 30 supplies.

The circuit 12 which generates the carrier signal is formed
by a frequency converter circuit 32, which receives the
analog clock signal at the reference frequency f_0 and supplies
30 an analog signal at the frequency of the carrier fp. The
carrier signal fp is supplied to two parallel carrier
branches, of which one 33 supplies the carrier signal in
phase, and the other 34 comprises a $\pi/2$ phase-shifting

circuit 35 which supplies a carrier signal in quadrature at frequency fp.

The modulation frequency fM is chosen so that:

$$8fc \le fM$$

where fc = Max(fci), and fci designates the chip rhythms fc1, fc1', fc2, fc2' of the navigation codes C1, C2, C1', C2', each fci value being such that fM = Ni.fci, Ni being an integer greater than or equal to 8, two navigation codes C1, C1' being quadrature modulated at frequency f1 = fp-fM/8, and two other navigation codes C2, C2' being quadrature modulated at frequency f2 = fp+fM/8, and the modulated navigation signal presenting a constant envelope. In particular, fM is chosen to be $\le$ 400 MHz, and more particularly, fM is chosen to be $\le$ 200 MHz, for an onboard device. Max designates the maximum function, fc being the greatest value of fci.

The various chip rhythms fci of the pseudorandom navigation codes (cadencing frequencies of these codes) are all greater than 0.5 MHz, and preferably greater than 1 MHz. Typically, in the Galileo constellation, the intended chip rhythm is 2.046 MHz for all codes.

In practice, the four codes can have the same chip rhythm, i.e. fci = fc. Nevertheless, nothing prevents using codes with different rhythms, provided that they satisfy the condition fM = Ni.fci.

The frequency of the carrier fp must be greater than 500 MHz, and is typically between 1000 MHz and 1700 MHz. For example, in the context of the Galileo constellation, band E5a is at a

carrier frequency of 1176.45 MHz and band E5b is at a carrier frequency of 1207.14 MHz. Band E1 is at 1589.742 MHz and band G1 extends as far as 1610 MHz.

5 The modulator circuit 13 comprises a logic circuit 45, which supplies, at its output 36, a baseband 8-PSK modulation signal at frequency fM, carrying the four navigation codes C1, C2, C1', C2'. This modulation signal can thus take eight phase states, corresponding to the constellation of 8-PSK

10 modulation, i.e. to the various contacts P1, P2, P3, P4, P5, P6, P7, P8 of this constellation, as shown in Fig. 8.

To develop this modulation signal, the logic circuit 45 uses four navigation codes, e.g. according to the following truth

15 table:

TABLE 1

C1(t)	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1
C2(t)	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	1
C1'(t)	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1
C2'(t)	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1
t modulo 8TM																
[0,TM[	P5	P4	P4	P3	P6	P7	P5	P2	P6	P1	P3	P2	P7	P8	P8	P1
[TM,2TM[	P5	P8	P4	P3	P6	P7	P5	P6	P2	P1	P3	P2	P7	P8	P4	P1
[2TM,3TM[	P1	P8	P4	P7	P6	P7	P5	P6	P2	P1	P3	P2	P3	P8	P4	P5
[3TM,4TM[	P1	P8	P8	P7	P2	P7	P5	P6	P2	P1	P3	P6	P3	P4	P4	P5
[4TM,5TM[	P1	P8	P8	P7	P2	P3	P1	P6	P2	P5	P7	P6	P3	P4	P4	P5
[5TM,6TM[	P1	P4	P8	P7	P2	P3	P1	P2	P6	P5	P7	P6	P3	P4	P8	P5
[6TM,7TM[	P5	P4	P8	P3	P2	P3	P1	P2	P6	P5	P7	P6	P7	P4	P8	P1
[7TM,8TM[	P5	P4	P4	P3	P6	P3	P1	P2	P6	P5	P7	P2	P7	P8	P8	P1

In this truth table, TM equals 1/fM.

This truth table corresponds to the expression of the baseband modulation signal x(t) which is supplied at the
5 output 36 according to the following equations:

$$x(t) = \frac{2}{\sqrt{2}} \cdot [sign[\cos(2\pi(fM/8)t + k1\pi/2]] + j.k2sign[\cos(2\pi(fM/8) + k1\pi/2]$$

or
10

$$x(t) = 2(j)^{k1} \cdot sign[\cos(2\pi(fM/8)t + k2\pi/4]$$

with   k1 ε {1,2,3,4} and k2 = ±1

15 These equations can themselves be obtained from the
expression of the baseband modulation signal of a modulation
of LOC type with a sinusoidal subcarrier, but making this
modulation discrete so that only the point phase states of
the same amplitude are retained.
20

It is clear that it is also possible to use one of the seven
other truth tables which are defined starting with this truth
table TABLE 1, by simple rotation by n.π/4, where n is an
integer between 1 and 7. In fact, the constellation of Fig. 8
25 corresponds to eight equivalent constellations, depending
only on the position which is chosen for one of the contacts,
e.g. contact P1.

It should also be noted that the eight truth tables which can
30 be obtained with a constellation similar to that of Fig. 8
but with contacts which are passed through clockwise (and not

anticlockwise as in Fig. 8) are actually identical, apart from the rotation, to the eight truth tables defined previously, and can therefore also be used. In fact, it is enough to invert C1, C1' and C2, C2' to go from a constellation which is passed through in one direction to the constellation with the same contacts but passed through in the reverse direction.

It is equally possible to use the following truth table:

TABLE 2

C1(t)	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1
C2(t)	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	1
C1'(t)	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1
C2'(t)	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1
t modulo 8TM																
[0,TM[	P1	P8	P4	P7	P6	P7	P5	P6	P2	P1	P3	P2	P3	P8	P4	P5
[TM,2TM[	P1	P8	P8	P7	P2	P7	P5	P6	P2	P1	P3	P6	P3	P4	P4	P5
[2TM,3TM[	P1	P8	P8	P7	P2	P3	P1	P6	P2	P5	P7	P6	P3	P4	P4	P5
[3TM,4TM[	P1	P4	P8	P7	P2	P3	P1	P2	P6	P5	P7	P6	P3	P4	P8	P5
[4TM,5TM[	P5	P4	P8	P3	P2	P3	P1	P2	P6	P5	P7	P6	P7	P4	P8	P1
[5TM,6TM[	P5	P4	P4	P3	P6	P3	P1	P2	P6	P5	P7	P2	P7	P8	P8	P1
[6TM,7TM[	P5	P4	P4	P3	P6	P7	P5	P2	P6	P1	P3	P2	P7	P8	P8	P1
[7TM,8TM[	P5	P8	P4	P3	P6	P7	P5	P6	P2	P1	P3	P2	P7	P8	P4	P1

In this truth table, TM equals 1/fM.

This truth table corresponds to the expression of the baseband modulation signal x(t) which is supplied at the output 36 according to the following equations:

$$x(t) = \frac{2}{\sqrt{2}} \cdot [sign[\sin(2\pi(fM/8)t + k1\pi/2]] + j.k2 sign[\sin(2\pi(fM/8) + k1\pi/2]$$

or

5
$$x(t) = 2(j)^{k1} \cdot sign[\sin(2\pi(fM/8)t + k2\pi/4]$$

with k1 ε {1,2,3,4} and k2 = ±1

It is also possible to use one of the seven other truth
tables which are defined starting with this truth table
10 TABLE 2, by simple rotation by n.π/4, where n is an integer
between 1 and 7.

Here too, the eight truth tables which can be obtained with a
similar constellation but with contacts which are passed
15 through in the reverse direction are actually identical,
apart from the rotation, to the eight truth tables defined
previously, and can therefore also be used.

There are thus thirty-two truth tables in the group of truth
20 tables which can be used and corresponding to the
constellation shown in Fig. 8, where the eight contacts are
distributed symmetrically on a circle (constant amplitude)
and phase-shifted by π/4, four contacts being on the axes of
the Fresnel plan.
25
Thus the method according to the invention can be assimilated
to modulation of alternative BOC type (with two frequencies
f1 and f2 around the carrier frequency and separated from
this carrier frequency by a subcarrier frequency of value
30 fM/8), but defined starting with a subcarrier of cosine or
sine type (such as is used for LOC modulation, of which only

certain discrete points are exploited, to ensure that the baseband modulation signal is of constant amplitude).

The baseband modulation signal x(t) which is supplied at the
5 output 36 of the modulation logic circuit 45 is supplied to
one branch 37 in phase and to one branch 38 in quadrature.
The in-phase branch 37 comprises a filter 39 which extracts
the in-phase values I from the modulation signal, and a
mixer 40 which combines them with the carrier signal at
10 frequency fp from the in-phase carrier branch 33. Similarly,
the in-quadrature branch 38 comprises a filter 41 which
extracts the in-quadrature values Q from the modulation
signal, and a mixer 42 which modulates these values onto the
carrier signals at frequency fp, which the in-quadrature
15 carrier branch 34 supplies. The signals, modulated in phase
(at the output of the branch 37) and in quadrature (at the
output of the branch 38), are combined by an in-phase adder
circuit 43, which supplies a single modulated signal at the
output 44, which is connected to the input of the
20 amplification and filtering emitter circuit 15, for emission
of the modulated navigation signal 7.

Fig. 7 gives an example of timing diagrams for the four codes
C1, C2, C1', C2' and for the paths I and Q of the modulation
25 signal which are used at the input of the mixer circuits 40,
42. With this modulation signal, the modulated signal which
is supplied at the output 44 presents a constant envelope.

Figs. 5 and 6 represent two implementation variants of an
30 architecture for the receiver 6, for exploitation of the
modulated navigation signal by the device according to the
invention. In the variant of Fig. 5, a single branch is used
for reception and processing of the navigation signal. Thus

the radio frequency reception chain comprises the reception antenna 18, which is connected to a low noise amplifier 46, followed by a frequency conversion circuit 47, which converts the received signal from frequency fp to an intermediate

5 frequency fi, which is suitable for the adapted receiver, to then make analog/digital conversion possible in the best possible conditions. The signal is then transmitted to a bandpass filter 48, which makes it possible to keep in the modulated navigation signal only the two main lobes

10 corresponding to frequencies f1 and f2, eliminating the components outside these lobes. Thus the pass band of the bandpass filter 48 is greater than or equal to 2fM/8+2fc, and preferably of the order of this value, corresponding to the frequency spread of the two lobes of the navigation signal at

15 frequencies f1 and f2. The thus filtered signal is supplied to an analog/digital converter 49, which supplies a corresponding digital signal to signal processing circuits 50, which together form one of the signal processing circuits 20 described above with reference to Fig. 3. The

20 various circuits 50 each make it possible to process the various pseudorandom navigation codes C1, C2, C1', C2', jointly or otherwise. The number of circuits 50 depends on the use which is made of the receiver and of the services which are accessible to the user of this receiver. It is thus

25 possible that the receiver is authorized to exploit only some of the codes, e.g. C1 and C1'.

In the variant of Fig. 6, the two frequencies f1 and f2 are processed separately on two distinct branches. Thus the

30 output of the amplifier 46 feeds a first branch 51 and a second branch 52 in parallel. On the first branch 51, the lobe which is centered on the frequency f1 of the navigation signal is processed. This branch 51 thus comprises a

circuit 53 to convert the frequency f1 to the intermediate
frequency fi, followed by a bandpass filter 54 which makes it
possible to keep only the lobe at frequency f1, the pass band
of the filter 54 being between 2fM/8 and 2fc, an

5   analog/digital converter 55, and multiple signal processing
circuits 56 to extract the two navigation codes C1, C1'.
Similarly, the branch 42 comprises a frequency conversion
circuit 57 (from f2 to fi), followed by a bandpass filter 58
of pass band between 2fM/8 and 2fc, making it possible to

10 extract the components at the lobe of frequency f2, an
analog/digital converter 59, and signal processing circuits
60 to extract the codes C2, C2'.

Fig. 9 represents an example of a spectrum of a modulated

15 navigation signal such as is transmitted by the payload
(emitter). The central frequency is fp. As can be seen, this
signal comprises two main lateral lobes, one at frequency f1,
the other at frequency f2.

20 Fig. 10 represents an example of a spectrum of a modulated
navigation signal which is obtained after bandpass filtering
by the filter 48 of Fig. 5 in a receiver. As can be seen,
this signal comprises two main lateral lobes, one at
frequency f1, the other at frequency f2.

25

Fig. 11 represents an example of a spectrum of a modulated
navigation signal which is obtained after bandpass filtering
by the filter 54 in a receiver of Fig. 6. Only the lobe which
is centered by frequency f1 is present. This lobe contains

30 the signals C1 and C1'.

Fig. 12 is the correlation function of the signal, with the
spectrum of Fig. 11 correlated with the replica of the

codes C1 and C1', as generated by the receiver. The
correlation peak (almost triangular shape) indicates the
presence of the codes C1 and C1' in the signal of Fig. 11,
and thus excellent correlation.

5

The results shown in Figs. 11 and 12 were obtained by
navigation signal simulation software, with a pass band of
40 MHz for the filter 53, a frequency f1 corresponding to
band E5a, and a value of fM = 120 MHz.

10

The navigation codes which are used are four pseudorandom
codes of the type which is intended for the Galileo
constellation.

15   The invention described above and shown in the figures can be
the subject of numerous implementation variants.

In particular, the receiver architectures can be very
different, and there are numerous known technologies in this
20   matter. The various described functions can also be the
subject of diverse structural implementations, which are well
known per se.

Additionally, it is also possible to imagine using an 8-PSK
25   modulation which is not symmetrical as shown and described
above, but asymmetrical, the points P1 to P8 not being
symmetrical to each other around the origin of the Fresnel
plan.

30   Preferably, the value of fc is of the order of 10 MHz, and
the value of fM is of the order of 120 MHz. Nevertheless,
other values are possible and compatible with a navigation
method and device according to the invention.